A37 contd.

37. A device manufacturing method including a process for transferring, through projection exposure, a pattern of a mask onto a wafer by use of a projection exposure apparatus as recited in claim 36. --

REMARKS

Applicants request favorable reconsideration and allowance of the subject application in view of the preceding amendments and the following remarks.

To place the subject application in better form, the specification has been amended to correct minor informalities, including those noted by the Examiner. Also, a new Abstract is presented in accordance with preferred practice. Further, by separate paper, Applicants request approval to correct minor informalities in Figures 38, 66 and 69. No new matter has been added by these changes.

Claims 18-37 are presented for consideration in lieu of claims 1-17, whih have been canceled without prejudice or disclaimer. Claims 18, 20, 22, 23, 25, 26, 28, 30, 32, 33, 35 and 36 are independent. Support for claims 18-37 can be found in the original application, as filed. Therefore no new matter has been added.

Applicants request favorable reconsideration and withdrawal of the objections and rejections set forth in the above-noted Office Action.

The specification and drawings were objected to on formal grounds. Applicants submit that the foregoing changes overcome these objections. Such favorable indication is requested.

Turning now to the art rejections, claims 1, 2, 4 and 5 were rejected under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 5,013,133 to Buralli et al. Claims 1 and 3 were rejected under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 4,983,017 to Tsuji et al. Claims 1, 4 and 5 were rejected under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 5,260,828 to Londono et al. Claims 14 and 16 were rejected under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 5,754,340 to Ushida et al. Claim 12 was rejected under 35 U.S.C. § 103 as being unpatentable over the Londono et al. in view of official notice. Applicants submit that the cited art does not teach or suggest many features of the present invention, as previously recited in claims 1-17. Therefore, these rejections are respectfully traversed. Nevertheless, claims 18-37 are now presented to amplify the distinctions between the present invention and the cited art.

In one aspect of the invention, independent claim 18 recites an optical system that includes a diffractive optical element, which is able to be deformed by weight thereof and at least one optical member for preventing a change in optical performance of the optical system due to deformation of the diffractive optical element when the diffractive optical element is provided in the optical system.

Applicants submit that the cited does not teach or suggest such features of the present invention, as recited in independent claim 18.

The Buralli et al. document shows an imaging optical system having a diffractive optical element and a phase corrector for correcting aspherical aberration. The Tsuji et al. patent relates to an optical head device in which plural diffractive optical elements having different

optical characteristics are provided on the same plane. These patents, however, are completely silent as to any possibility of deformation of the diffractive optical element. In turn, these patents are silent with respect to any possibility of a change in optical performance of the optical system due to deformation of the diffractive optical element. Accordingly, Applicants submit that these patents do not teach or suggest the salient features of Applicants' present invention, as recited in independent claim 18.

The Londono et al. patent relates to reducing variations of a lens and a lens device induced by temperature. That patent shows a lens system having a surface 14 with a refractive power and a surface 16 with a diffraction grating. That patent teaches an arrangement in which, even if the size or refractive index of the lens changes due to temperature variation, the power of the lens, that is, the focal length thereof, is maintained unchanged.

The Londono et al. patent refers to deformation of the surface 16 with a diffraction grating (which may correspond to a diffractive optical element) due to temperature variation. That patent, however, is completely silent with respect to the possibility of deformation of the diffraction grating due to weight thereof. In turn, that patent is silent regarding how to correct for a change in optical performance of the optical system due to deformation of the diffractive optical element caused by weight thereof. Accordingly, the Londono et al. patent likewise does not teach or suggest the salient features of Applicants' present invention, as recited in independent claim 18.

In another aspect of the invention, independent claim 20 recites an optical system that includes a diffractive optical element, which is able to be deformed by fixing the diffractive

optical element in the optical system, and at least one optical member for preventing a change in optical performance of the optical system due to deformation of the diffractive optical element when the diffractive optical element is provided in the optical system.

Applicants submit that the cited art also does not teach or suggest such features of the present invention, as recited in independent claim 20.

As discussed above, the Buralli et al. patent and the Tsuji et al. patent are silent as to any possibility of deformation of a diffractive optical element, or to any possibility of a change in optical performance of an optical system due to deformation of a diffractive optical element.

The Londono et al. patent, although referring to deformation of the surface 16 with a diffracting grating, due to temperature variation, that patent also is silent as to the possibility of deformation of the diffraction grating caused by fixing the diffractive optical element in the optical system, such as, for example, by pressure applied to the lens from a supporting member or the light emitting member. In turn, that patent teaches nothing regarding how to correct for a change in optical performance of the optical system due to corresponding deformation of the diffractive optical element.

Accordingly, Applicants submit that the Buralli et al., Tsuji et al., and Londono et al. patents likewise do not teach or suggest the salient features of Applicants' present invention, as recited in independent claim 20.

The remaining art cited does not cure the deficiencies noted above with the respect to the Buralli et al., Tsuji et al., and Londono et al. patents.

For the foregoing reasons, Applicants submit that the present invention, as recited in independent claims 18 and 20, is patentably defined over the cited art, whether that art is taken individually or in combination. Independent claims 22, 23, 25, 26, 28, 30, 32, 33, 35 and 36 likewise should be deemed allowable over the cited art, for defining other patentable features of the present invention.

The dependent claims also should be deemed allowable, in their own right, for defining other patentable features of the present invention in addition to those recited in their respective independent claims. Individual consideration of these dependent claims is requested.

Applicants further submit that the instant application is in condition for allowance. Favorable reconsideration, withdrawal of the objections and rejections set forth in the above-noted Office Action and an early Notice of Allowance are requested.

Applicants' undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should be directed to our address listed below.

Respectfully submitted,

Attorney for Applicants
Steven E. Warner
Registration No. 33,326

FITZPATRICK, CELLA, HARPER & SCINTO
30 Rockefeller Plaza
New York, New York 10112-3801
Facsimile: (212) 218-2200

SEW/eab

Application No. 09/362,698
Attorney Docket No. 684.2621CIP

APPENDIX A

IN THE ABSTRACT

Please cancel the current abstract and insert the following:

-- An optical system includes a diffractive optical element, which is able to be deformed by weight thereof and at least one optical member for preventing a change in optical performance of the optical system due to deformation of the diffractive optical element when the diffractive optical element is provided in the optical system. --

IN THE SPECIFICATION:

Please amend the specification as follows.

Please substitute the paragraph beginning at page 2, line 5 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 1 shows a binary type diffractive optical element. This binary type diffractive optical element has a diffractive optical surface 204, having been formed by removing, from the shape of a flat-convex type refraction lens 201 (Figure 1, (A)), portions that provide an optical path difference corresponding to n times the wavelength (n is an integer), and by quantizing the shape of a resultant diffractive optical element 202 (with a shape shown in Figure 1, ([b]B)) with

a thickness corresponding to a fraction of the wavelength so that the shape is approximated with a step-like structure such as shown in Figure 1, (C). --

Please substitute the paragraph beginning at page 2, line 18 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- In Figure 1, denoted at 203 and 205 each is a transparent substrate on which a diffractive optical surface 202 or 204 with a fine shape is formed. --

Please substitute the paragraph beginning at page 2, line 21 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 2 illustrates manufacturing processes for a known binary type diffractive optical element having a four-step (level) structure. Denoted in the drawing at 300 is a transparent glass substrate (refractivity: n), and denoted at 301 is a resist. Denoted at 302 is a mask to be used for a first exposure, and denoted at 303 or 306 is exposure light. Here, the resist 301 comprises a positive type resist. --

Please substitute the paragraph beginning at page 3, line 2 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- First, in process A, the pattern of the mask 302 is transferred onto the resist 301 by means of exposure light 303. In process B, development of the resist 301 is performed and, in process C, etching of the glass substrate 300 is executed. Then, in process D, unnecessary resist

material on the glass substrate 300 is removed, whereby a binary type diffractive optical element with a two-step (level) structure is completed. --

Please substitute the paragraph beginning at page 3, line 17 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Subsequently, a resist 304 is again applied to the glass substrate 300 having a binary type diffractive optical element with a two-level structure formed thereon, and in process E a second exposure is performed by use of a mask 305. The pattern of the mask 305 has a pitch a half of that of the pattern of the mask 302. The exposure is performed while accurately registering the edge of a light blocking portion of the mask 305 with the edge of the two-level binary structure. Then, after a developing process in process F, a resist pattern such as illustrated is provided. --

Please substitute the paragraph beginning at page 4, line 2 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Subsequently, in process G, a second etching process is performed and, in process H, unnecessary resist material is removed, whereby a binary type diffractive optical element with a four-step (level) structure is accomplished. Here, the depth d2 of etching defined by the second etching process is determined by:

$$d2 = \frac{\lambda}{4(n-1)}$$

--.

Please substitute the paragraph beginning at page 4, line 9 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- These processes are concerned with a four-level structure and, as is well known, by repeating these processes, a binary type diffractive optical element of <u>an</u> eight-level or <u>a</u> sixteen-level structure can be produced. --

Please substitute the paragraph beginning at page 4, line 22 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The approximation of <u>a</u> step-like shape may lead to a small decrease of diffraction efficiency. Practically, however, a diffraction efficiency of about 95% (with eight-step approximation) or about 99% (with sixteen-step approximation) will be attainable, and there will be no practical problem. --

Please substitute the paragraph beginning at page 12, line 9 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figures 34, 35, 36, 37, 38, 39 and 40 <u>are</u> schematic views, respectively, for explaining examples of bonding. --

Please substitute the paragraph beginning at page 12, line 24 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 60 is a schematic view for explaining a [boding] bonding operation. --

Please substitute the paragraph beginning at page 13, line 16 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 3 is a section view of a main portion of a first embodiment of the present invention. Denoted in the drawing at 101 is a diffractive optical element, wherein a diffractive optical surface is formed on a transparent substrate 104. Denoted at 102 is a correction optical element for correcting or compensating for a change in optical characteristic of the diffractive optical element 101 due to deformation by weight of the same. The correction optical element 102 comprises a transparent substrate 106 having a aspherical surface 103 of revolutionally symmetrical shape with respect to an optical axis 105. --

Please substitute the paragraph beginning at page 16, line 6 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- In this embodiment, the influence of a change in shape of the substrate 401 due to deformation by weight is considered, and a change in phase distribution function of the diffractive optical element is disregarded. This is because the amount of deformation by weight in a direction perpendicular to the direction of gravity force is generally at a low level that can be disregarded, as compared with the amount of deformation in the direction of gravity force. For example, as shown in Figure 5, portion (B), a diffractive optical element 502 being deformed has approximately the same pitch (e.g., pitch p) as the pitch of phase distribution function of the

diffractive optical element 101 (Figure 5, portion (A)) before deformation by weight. This means that the position in the radius direction r of each ring boundary is unchanged before and after the deformation. --

Please substitute the paragraph beginning at page 16, line 24, and ending on page 17, line 10 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Since deformation, by weight, of optical elements other than the diffractive optical element 101 can be disregarded, the influence of deformation of the diffractive optical element in the optical system appears as a change in surface shape of the substrate 104 and a change in surface interval before and after the substrate 104. Here, the surfaces of the diffractive optical element 101 are denoted by s and s+1, and it is assumed that the diffractive optical element 101 is formed on the surface s (in this embodiment, s = 1). Also, the surface interval between the substrate 104 of the diffractive optical element 101 and the correction optical element 102 is here denoted as ds+1 (see [Figs.] Fig. 3). --

Please substitute the paragraph beginning at page 17, line 11 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The substrate shapes of the first and second surfaces of the substrate 104 are expressed as a general formula of an aspherical surface, as follows:

$$x = \{ch^2/1+\sqrt{1-(1+k)c^2h^2]}\}+Ah^4+Bh^6+\ldots \qquad \ldots (6)$$ --.

Please substitute the paragraph beginning at page 20, line 11. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Next, a case where there is deformation by weight produced in the diffractive optical element 601 and where degradation of imaging performance due to the influence of deformation has not yet been corrected by the aspherical surface provided on the correction optical element 602, will be described. Numerical example 2 below shows numerical data of the optical system in such a case, and Figure 7B shows corresponding image performance. Thus, in accordance with equations (4) and (8), the diffractive optical element 601 and the surface spacing ds+1 are deformed or changed. Also, there is no aspherical surface provided at this stage on the correction optical element 602. As seen from Figure 7B, spherical aberration becomes worse, as a result of deformation by weight of the diffractive optical element. --

Please substitute the paragraph beginning at page 23, line 13, and ending pon page 24, line 6 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Both surfaces of the substrate 804 may be formed into aspherical surfaces. It is to be noted that the aspherical surface may not always be revolutionally symmetrical with respect to the optical axis. Any aspherical surface shape may be used, provided that the shape is effective to compensate for deformation of the diffractive optical element. Also, substantially the same advantageous results will be attainable when the structures of this embodiment described above are incorporated into a portion of an optical arrangement including optical systems in addition to a diffractive optical element and a correction optical element. For example, a correction optical element for compensating for the effect of deformation by weight of a diffractive optical element may be disposed in proximity to a portion of an imaging optical system, having plural optical elements, where the diffractive optical element is provided. Similar effects of correcting degradation of imaging performance are provided in this case, like the embodiment described above. --

Please substitute the paragraph beginning at page 25, line 7 with the following. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Next, an optical unit having a diffractive optical element according to another embodiment of the present invention, will be described. --

Please substitute the paragraph beginning at page 26, line 20. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 12 shows an embodiment wherein a diffractive optical element 10 has a diffractive optical surface 10a, faced downwardly, on the surface opposite to a reinforcing ring 11. The manner of unitization and advantageous results therefrom are essentially the same as <u>in</u> the preceding embodiment. --

Please substitute the paragraph beginning at page 29, line 20, and ending on page 30, line 8. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- A pattern of the reticle 15 is projected with light from the light source 16 and through the projection optical system 13, [on to] <u>onto</u> the wafer W with precision. Here, since the diffractive optical element 10 has a function equivalent to a lens having a very high refractivity, as compared with an ordinary lens, use of the diffractive optical element is very effective for correction of aberrations. Also, as regards correction of chromatic aberration, an example of chromatic aberration correction based on the combination of a refraction lens and a diffractive optical element is shown in Japanese Laid-Open Patent Application, Laid-Open No. 242373/1994. Further, the diffractive optical element 10 may provide an aspherical surface effect, just by changing its pitch or shape. --

Please substitute the paragraph beginning at page 30, line 9. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 16 is a flow chart of a procedure for the manufacture of microdevices such as semiconductor chips (e.g., ICs or LSIs), liquid crystal panels, or CCDs, for example, by use of an exposure apparatus such as shown in Figure 9 or 15. --

Please substitute the paragraph beginning at page 30, line 14 and ending on page 31, line 5. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Step 1 is a design process for designing a circuit of a semiconductor device. Step 2 is a process for making a mask on the basis of the circuit pattern design. Step 3 is a process for preparing a wafer by using a material such as silicon. Step 4 is a wafer process (which is called a pre-process) wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step (which is called a post-process) wherein the wafer having been processed by step 4 is formed into semiconductor chips. This step includes an assembling (dicing and bonding) process and a packaging (chip sealing) process. Step 6 is an inspection step wherein an operation check, a durability check and so on for the semiconductor devices provided by step 5, are carried out. With these processes, semiconductor devices are completed and they are shipped (step 7). --

Please substitute the paragraph beginning at page 32, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- A [Description] description will now be made to further embodiments of the present invention. --

Please substitute the paragraph beginning at page 32, line 8. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Some embodiments to be described below are directed to an optical element having two or more optical members adhered or bonded together. In order to avoid creation of clearance due to an adhesive agent or degradation of flatness resulting therefrom, one or both of <u>the</u> bonding areas are provided with a groove which may function to reduce a residual stress to be produced by a force applied by the bonding. The groove may function to prevent creation of clearance due to an adhesive agent jutted out or degradation of flatness resulting therefrom, or may function to assure that the bonding is performed only at the groove portion. --

Please substitute the paragraph beginning at page 33, line 14. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figures 19A - 19D are schematic views, respectively, each showing in enlargement the portion A of Figure 18. In these drawings, denoted at 1003 is an adhesive agent, and denoted at 1004 is a groove (groove for receiving the adhesive agent.) In Figures 19A and 19B, the diffractive optical element 1002 is illustrated as being a four-level binary optics <u>arrangement</u> which may be determined through approximation based on quantization of a Kinoform. Howver, the invention is not limited to the quantization number (level number) of [a] binary optics. Thus, a Fresnel lens with a blazed shape may be used, with a result of advantageous effects of the present invention. --

Please substitute the paragraph beginning at page 36, line 22. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Alternatively, as shown in Figure 19D, the non-contact portion created in the optical contact may be bonded by using an adhesive agent. Also, [in] <u>on</u> such <u>an</u> occasion, the groove 1004 may be formed at the place closer to the center as compared with the adhesive agent but outside the effective diameter. --

Please substitute the paragraph beginning at page 36, line 21. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Where only the peripheral portion is to be adhered, the groove 1004 should be formed at a place closer to the center than the adhesive agent [ant] <u>and</u> outside the effective diameter, as shown in Figure 19C. --

Please substitute the paragraph beginning at page 38, line 16. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figures 21A and 21B are enlarged views of the portion B of Figure 20. The adhesive agent 1003 is provided by an inorganic series adhesive material of a low-melting-point glass. The low-melting-point glass has good characteristics such as a thermal expansion coefficient, for example, [in] <u>with</u> respect to adhesion of glasses. Thus, in combination with the attracting force of vacuum ambience, creation of unwanted stress or the like due to a change in environmental

temperature or a change in temperature resulting from absorption of light by the lens itself can be suppressed. --

Please substitute the paragraph beginning at page 39, line 1. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- As shown in Figure 21A [ore] or 21B, both of the plane-convex lens 1005 and the diffractive optical element 1002 may be formed with grooves 1004, defining the adhesion area. Where a metal eutectic crystal (Au and Al) is used as an example of inorganic series adhesion, both of the diffractive optical element 1002 and the plane-convex lens 1005 may be formed with grooves of a depth corresponding to the thickness (e.g., about 0.1 micron) of the vapor deposition of one metal (Au or Al) for the eutectic crystal. Metal films may be deposited on theses grooves, and the bonding based on the eutectic crystal may be performed. Another example of the bonding process may be anodic bonding. A glass with ions and an electrically conductive film may be formed in the film, and the bonding may be made through application of an electric field. The plane-convex lens 1005 or the diffractive optical element 1002 may be a glass with ions. As shown in Figure 21A, the grooves may be formed only at the bonding area, or, as shown in Figure 21B, the groove on the plane-convex lens side may be formed wide. --

Please substitute the paragraph beginning at page 39, line 23, and ending on page 40, line 5. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- While the embodiment has been described with reference to examples of optical contact for the adhesion of the central portion, the adhesion may be made over the whole surface or may be made only at the peripheral portion. Where the whole surface adhesion is to be made, an inorganic series adhesion process based on melting boding of a material, easily usable [in] with respect to optics, may be used. Examples of materials to be sued for the melting bonding are quartz, CAF_2, MgF and LiF. --

Please substitute the paragraph beginning at page 40, line 15. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The inorganic series [boding] bonding is effective to prevent a decrease of efficiency due to degradation of the adhesive agent, for example. Further, in the structure described above, the optical material that assures the strength may be provided by a lens which constitutes a projection optical system. It effectively contributes to reduction in total thickness of the optical members in the whole projection optical system, and minimizes the absorption of illumination light. --

Please substitute the paragraph beginning at page 41, line 7. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- As shown in Figure 23A, a groove 1004 is formed on the diffractive optical element 1002 side, so as to release distortion which may be produced at the bonding. However, there may be plural grooves formed. That is, where the bonding is to be made by using an adhesive

agent, as shown in Figure 23B, a groove 1004 may be formed on the diffractive optical element 1002 side so as to release the distortion which may be produced at the bonding and, additionally, another groove 1004 may be formed on the place-concave lens 1007 to prevent extension of the adhesive agent. [In] <u>On</u> that occasion, any residual stress created by the force applied at the [boding] <u>bonding</u> can be reduced and, in addition thereto, the surface of the diffractive optical element can be protected. The bonding strength may increase as a result. --

Please substitute the paragraph beginning at page 42, line 13. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The provision of such <u>a</u> groove is effective to prevent creation of clearance or degradation of flatness due to jutting-out of the adhesive agent, and assures that the bonding is made only at the groove areas, whereby several inconveniences can be avoided. --

Please substitute the paragraph beginning at page 43, line 24, and ending at page 44, line 9. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figures 27 and 28 are enlarged and sectional views, respectively, of a region A of Figure 26. The diffractive optical element 2021 has a fine surface-step pattern formed with precision through an ordinary semiconductor process. In Figures 27 and 28, this diffractive optical element 2021 is illustrated as being a quantized and approximated four-level binary optics <u>arrangement</u>. However, the number of quantization (number of levels) of the binary optics is not

limited to four, and an eight-level or sixteen-level structure may be used. Alternatively, a Kinoform with blazed shape may be used, with substantially the same optical effect. --

Please substitute the paragraph beginning at page 44, line 10. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 27 shows a case where the plane [plane] opposite to the face of the element 2021 where the surface-step pattern is formed is bonded to the parallel plane plate 2020. This example is advantageous [in] <u>with</u> respect to the strength since the bonding area is large. On the other hand, as shown in Figure 28, the bonding of the element 2021 may be made at the face where the surface-step pattern is formed. [In] <u>On</u> that occasion, deposition of dust or foreign particles to the surface-step pattern can be prevented, and thus the cleaning may be easy. An anti-reflection film of single-layer structure or multilayered structure may be formed at the bonding face. The topmost layer of such anti-reflection film may be provided by an oxide such as alumina, particularly, SiO_2, with a result of easy adhesion with the parallel plate 2020.--

Please substitute the paragraph beginning at page 44, line 27, and ending on page 45, line 17. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 29 is a sectional view of a bonding device. Fixedly mounted on a rotatable fixing tool 2023 is a diffractive optical element chuck 2024. Two, large and small, ring-like protrusions 2025 and 2026 having different diameters are formed on the top face of the chuck 2024, the protrusions being protruded upwardly. Between these protrusions 2025 and 2026,

there is a discharging outlet port 2027. The protrusion 2025 is made slightly lower than the protrusion 2026. Mounted on the outside peripheral surface of the fixing tool 2023 is a parallel plane holder 2029 of generally cylindrical shape, having a [thee] <u>three</u>-point abutment 2028. The parallel plane plate 2020 can be engaged with this abutment 2028, by which the center of the parallel plate 2020 placed on the holder 2029 can be brought into alignment with the center of the chuck 2024. Disposed above the chuck 2024 is a position measuring mark scope [2023] <u>2030</u>. --

Please substitute the paragraph beginning at page 45, line 18, and ending on page 46, line 8. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The diffractive optical element 2021 provided by a quartz wafer having a diffraction grating is placed on the chuck 2024, and, while observing the position measuring mark on the diffractive optical element 2021 through the mark scope 2030, the relative position is adjusted so that the center of the diffractive optical element 2021 is aligned with the center of the chuck 2024. Then, air[s] [are] <u>is</u> discharged through the outlet port 2027, by which the diffractive optical element 2021 is attracted to the protrusions 2025 and 2026. In response, the diffractive optical element 2021 deforms very small into a convexed shape. The centering of the diffractive optical element 2021 may be made by using the grating pattern itself, not by using a specific mark. The mark scope 2030 is moved out of the bonding device after the measurement, to a position not interfering with the bonding process. --

Please substitute the paragraph beginning at page 46, line 9. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- After completion of alignment between the centers of the diffractive optical element 2021 and the parallel plate 2020, the plate holder 2029 is moved downwardly. Then, the parallel plate 2020 first contact the center of the diffractive optical element 2021. Subsequently, air[s] [are] <u>is</u> discharged through the outlet port 2027 so as to gradually turn[s] the negative pressure to the atmospheric pressure, by which the deformation of the diffractive optical element 2021 is released. By this, the contact area between the diffractive optical element 2021 and the parallel plate 2020 increases gradually, and finally [they are] they are directly bonded with each other throughout the whole surface. --

Please substitute the paragraph beginning at page 46, line 23, and ending on page 47, line 10. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The direct bonding method such as described above is called "optical contact". It <u>is</u> the bonding method which is based on <u>a</u> hydrogen bond between quartz and water, water and water or fluorite and water, for example (Figure 30A), or which is based on direct bond of optical members through the van der Waals force (Figure 30B). This method enables bonding of optical members such as glass or quartz without use of an adhesive agent or the like. Here, in order to obtain a sufficient strength, the surface roughness of the bonding faces of the parallel plane plate 2020 and the diffractive optical element 2021 may preferably be kept at 5 nm or less in the mean square and the water content my preferably controlled to 10^{13} molecule/cm^2 or more.--

Please substitute the paragraph beginning at page 47, line 18, and ending on page 48, line 5. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Equation (10) above concerns a case where there is a clearance h at a single location. However, throughout the whole substrate of a diameter 200 mm, there may be a large number of clearances, and it is seen that the surface roughness which may be measured by AMF, for example, and the water content which may be measured by APIMS, for example, may provide a reference. Thus, in order to keep the surface roughness at the diffractive optical element 2021 surface, the diffractive optical element 2021 should be treated by polishing, for example, before it is treated by the semiconductor process, to keep <u>a</u> certain substrate surface roughness. Similarly, during or after the treatment, careful attention should be paid to hold the surface roughness. --

Please substitute the paragraph beginning at page 48, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- As regards the surface energy γ, for an ordinary quartz substrate, it is possible to keep the water content at 10^{13} molecule/cm^2 and, therefore, a sufficient surface energy γ can be kept. If, however, the surface is contaminated, the surface energy γ may become insufficient. In the case of a hydrophilic material such as quartz, the water content may be recovered by using a chemical liquid or using ultraviolet-ray or ozone washing. For a hydrophobic material, after the washing, water[s] may further be blown against it or any hydrophilic liquid treatment may be made to it, to thereby keep the water content. --

Please substitute the paragraph beginning at page 51, line 15. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Further, as shown in Figure 34, a diffractive optical element 2021 may be directly bonded to a parallel plane plate [2021] 2020 with the diffraction grating surface thereof facing up. Alternatively, as shown in Figure 35, two diffractive optical elements 2021 may be bonded together at their surfaces opposite to the surfaces on which their diffraction gratings are formed. As further alternatives, as shown in Figures 36 and 37, a diffractive optical element 2021 may be bonded, by direct bonding, to a central portion of a parallel plane plate 2020 without contact to the peripheral portion thereof, and the peripheral portion may be held by a holder. --

Please substitute the paragraph beginning at page 52, line 9. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 40 shows an example wherein the surface of a diffractive optical element 2021, opposite to the surface thereof where its diffraction grating is formed, is bonded to a prallel plane plate [2021] 2020. --

Please substitute the paragraph beginning at page 53, line 7. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 42 is a sectional view of another embodiment. A parallel plane plate [2031] 2032 made of quartz and having a diameter 200 mm and a thickness 0.725 mm and a diffractive optical element 2033 provided by a quartz wafer of a diameter 200 mm and a thickness 0.725

mm are bonded together in accordance with the direct bonding method like that of the embodiment of Figure 26. It is then incorporated into an optical system while being held by a holder 2022. As a result, the element 2033 shows an optical performance substantially the same as that of a diffractive optical element of a thickness 1.45 mm, and a rigidity of about four times higher as compared with a case where it is not bonded to the plate 2032. --

Please substitute the paragraph beginning at page 58, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 49 shows an example wherein the optical element 2041 is bonded to a plane-convex lens 2042 made of a fluorite material with a diameter 220 mm. Figure 50 shows an example where the optical element 2041 is bonded to a plance-[convex]concave lens 2043 made of quartz and having a diameter 200 mm. Figure [51] 52 shows an example where the optical element 2041 is bonded to a plane-aspherical lens 2044 made of a fluorite material and having a diameter 200 mm. Figure [52] 51 shows an example where a diffractive optical element 2045 comprising a rectangular substrate of a size 150 x 200 mm, being made of quartz and having a thickness 0.725 mm, and a cylindrical lens 2046 of a size 150 x 200 mm being made of quartz, are bonded together. --

Please substitute the paragraph beginning at page 59, line 2. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 53 is a sectional view of a yet further embodiment. This embodiment can be applied to a catoptric type optical system. A parallel plane plat 2047 made of SiC and having a diameter 200 mm and a thickness 30 mm and a diffractive optical element 2048 provided by a quartz wafer of a diameter 200 mm (eight inches) and a thickness 0.725 mm are bonded together in accordance with the direct bonding method like that of the embodiment of Figure 26. It is then held by a holder 2049 of a catoptric system. Since no optical characteristic is required for this parallel plane plate [2048] <u>2047</u>, a material of SiC having a relatively small thermal expansion coefficient, a good rigidity and a good thermal conductivity, is used in this example. However, other ceramics materials or metals may be used. Even for a reflection type diffractive optical element 2048 such as described above, an optical element with a fine grating pitch, having a good strength of about twice of higher rigidity, can be produced with good precision. It can be free from the influence of any external force, and can be incorporated into an optical system. --

Please substitute the paragraph beginning at page 64, line 13. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

Figure 61 is a flow chart for explaining the bonding procedure. The diffractive optical element 3016 is placed on the chuck 3012, and air[s] [are] <u>is</u> discharged outwardly through the outlet port 3017, whereby the optical element is held fixed by attraction. Here, since a negative pressure is produced in the space between the two protrusions 3014 and 3015, the portion of the diffractive optical element 3016 exposed to the negative pressure deforms toward the chuck

3012. As a result of this, moments are created at the outside peripheral portion of the diffractive optical element 3016, and the central portion of the diffractive optical element 3016 rises by a very small amount, while the contact point with the protrusion 3015 functions as a fulcrum. --

Please substitute the paragraph beginning at page 68, line 18, and ending on page 69, line 1. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The bonding surface of the diffractive optical element 3016 should be maintained free of contamination by particles, for example. If contamination is there, it may cause defective bonding, called a "void", and cleaning is necessary. Also, as regards the attracted water content at the surface of quartz which is influential to the hydrogen bond, only the environment in storage should be cared about, regardless of the cleaning method. Usually, it is about 10^{13} molecule/cm^2, and no particular problem will be caused with respect to the level. --

Please substitute the paragraph beginning at page 69, line 11. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- When a lens as bonded such as described above is used, it may be used in the state of a hydrogen bond, or it may be treated by heating to improve the bonding force. One of SOI (silicon on insulator) techniques having been reported is a cementing SOI technique, and, generally, when the heating treatment is performed in the state of a hydrogen bond, the state of bonding changes to a covalent bond. In the period until a complete covalent bond is accomplished, the state may be considered as being a coexistence of a hydrogen bond and a

covalent bond. The bonding strength increases with the increase of temperature in the heating process. Even with an optical glass containing an ordinary SiO_2 material as a major component, a similar procedure may be adopted to obtain good bonding. --

Please substitute the paragraph beginning at page 69, line 26, and ending on page 70 line 5. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Figure 64 is a sectional view of another embodiment. A diffractive optical element [3022] <u>3016</u> is held fixed by a fixing tool 3023 through a piezoelectric device 3024. A chuck 3022 is provided with a ring-like protrusion 3025, being protruded upwardly. At the top end of the holder 3023, there is a pressing member 3026 which is mounted detachably. --

Please substitute the paragraph beginning at page 70, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- When the diffractive optical element 3016 is fixed on the chuck 3022, it contacts first to the ring-like protrusion 3025 which is placed at a higher level than the other components. After this, the pressing member 3026 is put on the diffractive optical element 3016, from [the] above, and the pressing member is then held fixed on the holder 3023 by using fixing screws, not shown. Then, a voltage is applied to the piezoelectric device 3024, so as to press the chuck 3022 upwardly relative to the holder 3023. In this embodiment, to cause deformation of the diffractive optical element 3016, the chuck 3022 and the holder 3023 move relative to each other. As a result of this, moments are produced at the circumferential portion of the diffractive optical

element 3016 being in contact with the ring-like protrusion 3025 and the pressing member 3026, by which good bonding with a refractive lens (not shown), for example, is accomplished. --

Please substitute the paragraph beginning at page 70, line 25, and ending on page 71, line7. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The chuck 3022 and the holder 3023 may be made into an integral structure while omitting the piezoelectric device 3024, such that only tightening the fixing screws of the pressing member [3021] <u>3026</u> can produce deformation of the diffractive optical element 3016. However, use of the piezoelectric device 3024 may be preferably in that it assures stability of operation for applying uniform deformation regardless of the skill of the operator, for example. --

Please substitute the paragraph beginning at page 73, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- The diffractive optical element 3016 is placed on the chuck 3012 and, by using a mark scope 3018, adjustment is performed so that the center of the diffractive optical element 3016 is brought into alignment with the center of the chuck 3012. Due to the negative pressure between protrusions [3014] <u>3074</u> and 3015, the diffractive optical element 3016 is attracted to the chuck 3012. Due to the protrusions [3014] <u>3074</u> and 3015, the central portion of the diffractive optical element 3016 deforms by a very small amount. The centering of the diffractive optical element 3016 may be made by using the pattern of the diffractive optical element itself. After the

measurement, the mark scope 3018 moves outwardly of the bonding device to a place not interfering with the bonding operation. --

Please substitute the paragraph beginning at page 73, line 21, and ending on page 74, line 13. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- As the parallel plane plate 3032 is mounted on the three-point abutment 3033 of the holder 3034, the center of the chuck 3012 and the center of the parallel plane plate 3032 are registered with each other. After aligning the diffractive optical element 3016 with the center of the parallel plane plate 3032, first the parallel plane plate 3032 contacts with the center of the diffractive optical element 3016. By turning the negative pressure between the protrusions [3014] 3074 and 3015 gradually toward the atmospheric pressure, deformation of the diffractive optical element 3016 is released and thus the diffractive optical element 3016 and the parallel plane plate 3032 are gradually contacted with each other, whereby they are bonded by direct bonding. Use of the parallel plane plate holder [3014] 3034 having the abutment 3033 enables good bonding with the parallel plane plate 3032 with respect to which the measurement of its central position is difficult to attain because of the shape thereof. --

Please substitute the paragraph beginning at page 75, line 20, and ending on page 76, line 18. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Subsequently, as shown in Figure 68, the holder 3043 having the diffractive optical element 3016 attracted to the attracting groove 3046 is mounted on the tool 3041, so that the

diffractive optical element 3016 is disposed opposed to the flat face side of the lens 3046. The diffractive optical element 3016 is controlled with a distance of about [a] several tens of microns to the flat face of the plane-convex lens 3046. In this state, the tool 3041 as a whole is rotated by a predetermined angle to change the orientation of the diffractive optical element 3016, such that marks of the diffractive optical element 3016 can be measured by the mark scope 3047. then, like the embodiment described hereinbefore, the diffractive optical element 3016 is sequentially rotated each by 90 deg., and the amount of deviation of the marks in orthogonal directions is calculated. If the marks are formed at equidistant positions from the center of the diffractive optical element 3016, then a half of the positional deviation of the marks as observed throug the observation system being fixed corresponds to the amount of eccentricity. By moving the ring-like plate 3044 relative to the tool 3041, any eccentricity of the diffractive optical element 3016 with respect to the rotational shaft 3040 of the holder 3041 can be removed. --

Please substitute the paragraph beginning at page 79, line 15. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Subsequently, the frames 3051a and 3051b are moved pivotally around the hinge 3052 to bring the optical elements into contact with each other. Here, if, in the state where the virtual planes of the holder 3054a and 3054b, supporting the optical elements, are placed in parallel to each other, the distance between these virtual planes [are] is made smaller than the thickness of the lens 3046, then the contact of the optical elements is initiated from the portions close to the

hinge 3052. It is to be noted here that, eve if non-uniform contact is started, deformation of the elastic members 3053a and 3053b can absorb any discrepancy in geometrical arrangement. --

Please substitute the paragraph beginning at page 81, line 8, and ending on page 82, line 6. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Subsequently, as shown in Figure 75, the diffractive optical element 3016 and the parallel plane plate 3032 are disposed opposed to each other, and the diffractive optical element 3016 is held by the attracting groove 3045. The diffractive optical element 3016 is controlled with a distance of about [a] several tens of microns to the parallel plane plate 3032. In this state, the tool 3041 as a whole is rotated by a predetermined angle to change the orientation of the diffractive optical element 3016, such that marks of the diffractive optical element 3016 can be measured by the mark scope 3047. Then, like th embodiment described hereinbefore, the diffractive optical element 3016 is sequentially rotated each by 90 deg., and the amount of deviation of the marks in orthogonal directions is calculated. When two marks in orthogonal directions and at equidistant positions from the center of the diffractive optical element 3016 are measured by using the mark scope 3047 having its position held fixed, then a half of the positional deviation of the marks corresponds to the amount of eccentricity. By moving the ring-like plate 3044 relative to the tool 3041, any eccentricity of the diffractive optical element 3016 with respect to the rotational shift 3040 of the holder 3041 can be removed. --

Please substitute the paragraph beginning at page 82, line 15. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- As the material to be bonded, use may be made of a fluoride such as fluorite or quartz (e.g., lithium fluoride, barium fluoride, magnesium fluoride, or strontium fluoride). [In] On that occasion, if quartz is bonded by deformation, it can be done without any inconvenience. In a chase where fluorite having a Young's modulus close to that of the quartz is deformed, a similar procedure as having been described with reference to the preceding seven embodiments may be used to perform good bonding based on a hydrogen bond. --

Please substitute the paragraph beginning at page 82, line 25, and ending on page 83, line 4. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- Fluoride materials as fluorite (e.g., lithium fluoride, barium fluoride, magnesium fluoride, or strontium fluoride) may be bonded together. [In] On that occasion, even fluorite may be deformed in accordance with the procedure having been described hereinbefore, and good bonding based on a hydrogen bond may be accomplished similarly. --

Please substitute the paragraph beginning at page 83, line 5. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- A super-pure water of 0.05 cc by be dropped onto the surface to be bonded, and it may then be contacted to a refractive lens. Since in this state the optical elements to be bonded together may relatively shift easily, they may be held in a dry ambience gas while being fixed by

a holder. While it may be different depending on the ambience, after an elapse of a few hours or several tens of hour, a hydrogen bond with excessive water being removed may be accomplished, such that optical components may be bonded together tightly. According to experiments made by the inventors, it has been confirmed that, if heating treatment is performed in addition to holding the elements in a dry ambience gas, excessive water can be removed in a shorter time period. --

Please substitute the paragraph beginning at page 83, line 20. A marked-up copy of this paragraph, showing the changes made thereto, is attached.

-- In the embodiment described above, optical elements being bonded by a hydrogen bond may be placed in a closed casing filled with a nitrogen gas ambience, and a pressurizing treatment may be made to it. This is effective to increase the bonding strength. --